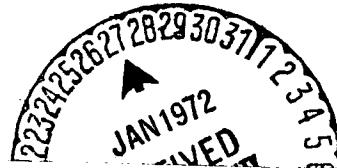


SOVIET "SOYUZ" SPACECRAFT

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SOVIET "SOYUZ" SPACECRAFT

ABSTRACT. The "Soyuz" program is discussed from the initiation through eight launchings, including the building of the world's first experimental space station. It is anticipated that "Soyuz" will, or could be, the basis for future developments in the field of permanent space stations.

The Soviet Union is carrying on a program of investigation and use of space ^{/2} in the interests of science, and of our national economy. This program envisages a combination of different vehicles:

- artificial earth satellites;
- automatic interplanetary stations;
- manned scientific and technical laboratories.

One of the main thrusts of the Soviet space program is to build permanent orbital stations that will make it possible to answer many of the cardinal questions of physics, geophysics, astrophysics, and, simultaneously, to use space for man's practical needs. Stations such as these will help use the earth's riches more intelligently, and will raise the development of geology, meteorology, agriculture, forestry, maritime fishing, geodesy, and oceanographic to a new level. These stations will play an important role in flights to the planets in the solar system, in the mastering of remote space.

Soviet scientists and designers, having systematically mastered space, several years ago began building new, manned, multipurpose spacecraft, the "Soyuz" spacecraft.

"Soyuz" spacecraft will be able to carry out complex investigations of near space and to work on the assembly of orbital stations. The use of the same spacecraft for different purposes will make the building of new orbital space systems easier and cheaper.

The principal task of the "Soyuz" program is to use the already developed "base spacecraft" as the basis for assembling the orbital station, and organiz-

* Numbers in the margin indicate pagination in the foreign text.

ing its supply and investigation of space.

The work on the "Soyuz" space program also is directed at long-term study of near space.

Included among the program's scientific tasks are:

detailed investigations of the earth, and of its atmosphere, for a more successful study of questions concerned with radiophysics, geophysics, and space navigation;

study of questions concerned with the use, for scientific and practical purposes, of the conditions prevailing in near space (high vacuum, weightlessness, radiation);

extra-atmosphere observations of the sun, stars, and planets and their satellites.

The ability of the "Soyuz" spacecraft to control its movements in space, to approach other space vehicles, and to maneuver in the immediate vicinity of them, is highly important for the building of scientific space stations from several self-contained sections placed in orbit.

The "Soyuz" spacecraft (Figure 1) consists of the cosmonauts' capsule, that is, of the recoverable vehicle, the orbital compartment, the service module, and the docking unit.

The cosmonauts' capsule, the recoverable vehicle, is designed to carry a crew into orbit, execute maneuvers in orbit, and return to earth. The temperature in the capsule at the time of landing is between 25 and 30°C, thanks to the heat-protective covering and the heat-insulated internal layer. The capsule contains the couches for the cosmonauts, the equipment and accessories for the spacecraft control systems, communications, and life-support. Containers hold the main and the reserve parachute systems. The spacecraft's control panel is installed in front of the central couch. The panel carries the instruments required to monitor the operations of the systems and units installed in the spacecraft, the navigation equipment, the television screen, and the switches for controlling the on-board systems. There is, in addition, an auxiliary panel for medical monitoring of the condition of cosmonauts when they are

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working in open space.

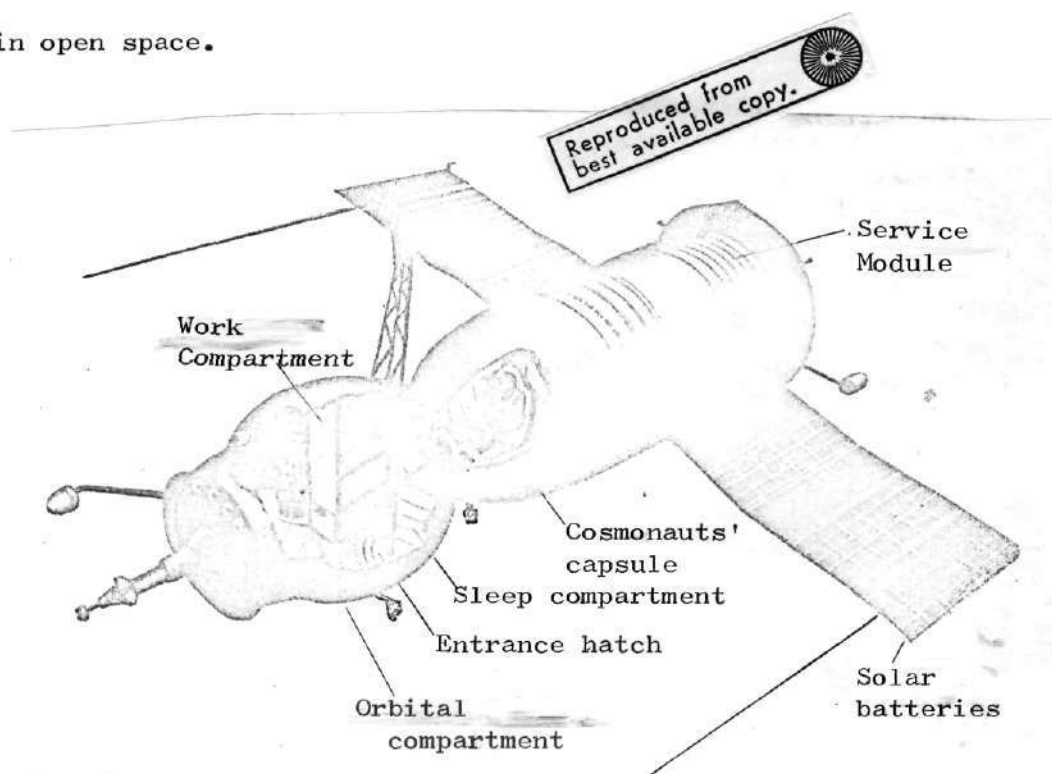


Figure 1. The "Soyuz" spacecraft.

The capsule ports are designed for visual observations, and for taking still photographs and motion pictures. An optical sight and orientation device is located in one of the ports, alongside the pilot's panel. To the right of the central couch is a lever for controlling the spacecraft's orientation around the center of mass, and to the left of it a lever for changing the linear speed of the spacecraft when maneuvering. The spacecraft is equipped for completely independent piloting without the participation of the ground command complex. Normal living conditions (pressure, gas composition, temperature, humidity) for the crew are created in the capsule. The cosmonauts therefore can work without suits. There is a food and water container. The upper part of the recoverable vehicle contains a hatch used by the cosmonauts to enter the capsule for the launch, and for entering the spacecraft's orbital compartment.

The recoverable vehicle of the "Soyuz" spacecraft has a number of advantages over the capsules of spacecraft built earlier. The shape of the recoverable vehicle, which is a segmental conical body resembling an automobile headlight, is such as to provide the necessary aerodynamic lift in flight in the atmosphere. The use of aerodynamic force on the descent trajectory makes it possible to reduce the G-force acting on the crew on the descent section to 3 to 4 units (compared with 8 to 10 units for earlier vehicles making a ballistic descent). The capability for maneuvering in the atmosphere in terms of altitude and direction of flight improves significantly the accuracy with which the vehicles can be landed. The ballistic trajectory can be used for the descent, if necessary. The rocket engines in the descent control system, and the soft landing rocket engines, are installed in the hull of the recoverable vehicle. /4

The orbital compartment is a scientific laboratory used by the cosmonauts for scientific observations and for resting, doing necessary physical exercises, and for eating. The orbital compartment can be used by the cosmonauts as a lock to leave the spacecraft for open space. Control and communication equipment, a portable television camera, motion picture and still cameras, and scientific instruments are provided in the working area and near the four ports in areas that make use convenient. The orbital compartment contains an all-wave radio receiver, in addition to the special communication equipment. The life-support units, food, scientific equipment, a first-aid kit, and toilet articles are located in a special "locker." The docking unit is installed in the nose of the orbital compartment.

The service module is designed to carry the on-board equipment and the spacecraft's rockets used in orbital flight. /5

Concentrated in the instrument bay are the units in the temperature control system and in the electrical supply system, the long-range radio communication and radiotelemetry equipment, and the instruments in the movement orientation and control system, together with the computers. The unpressurized part of the service module contains the two (main and backup) liquid-propellant rocket engines used for maneuvering in orbit, and for bringing the spacecraft back to earth. Each rocket engine has a thrust of 400 kg. The rocket engine installation

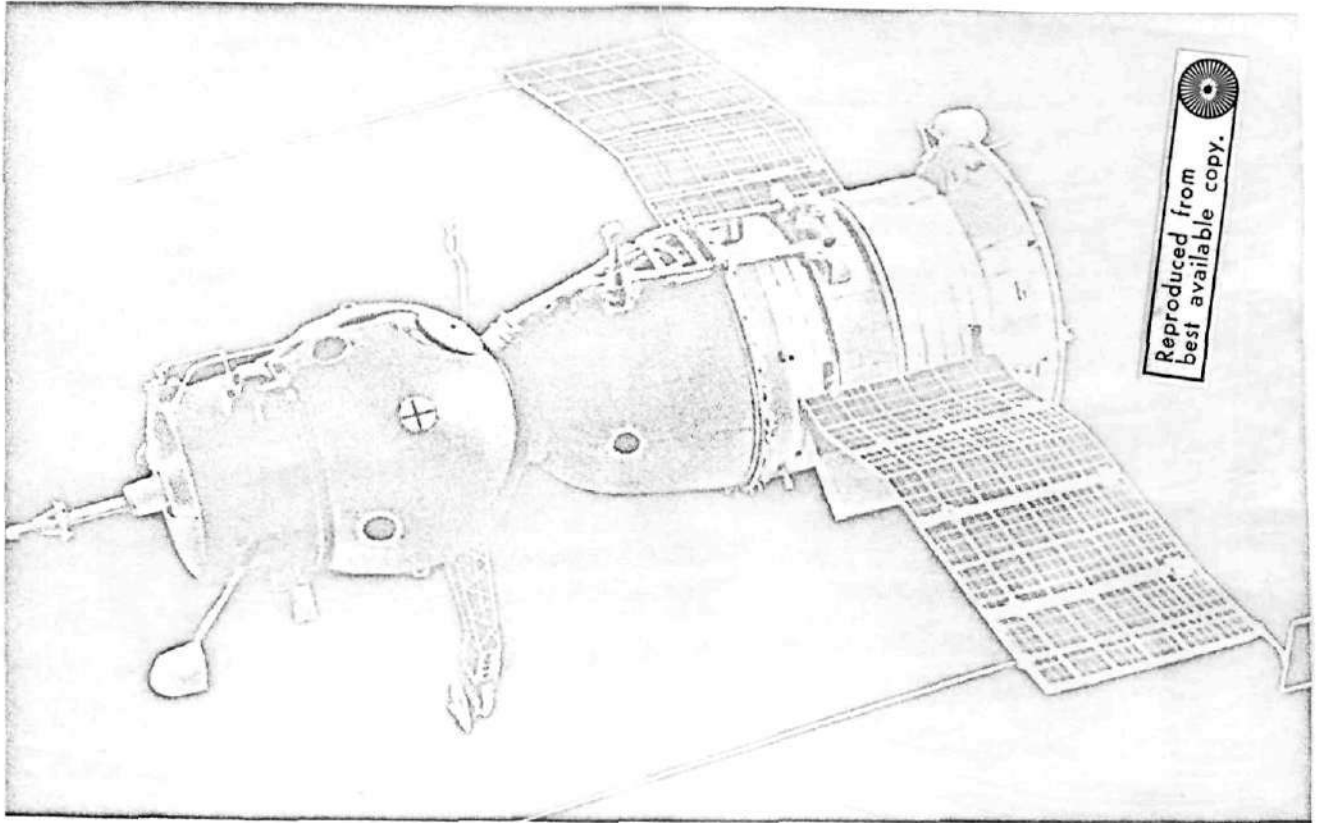


Figure 2. The "Soyuz" spacecraft with an "active" docking unit.

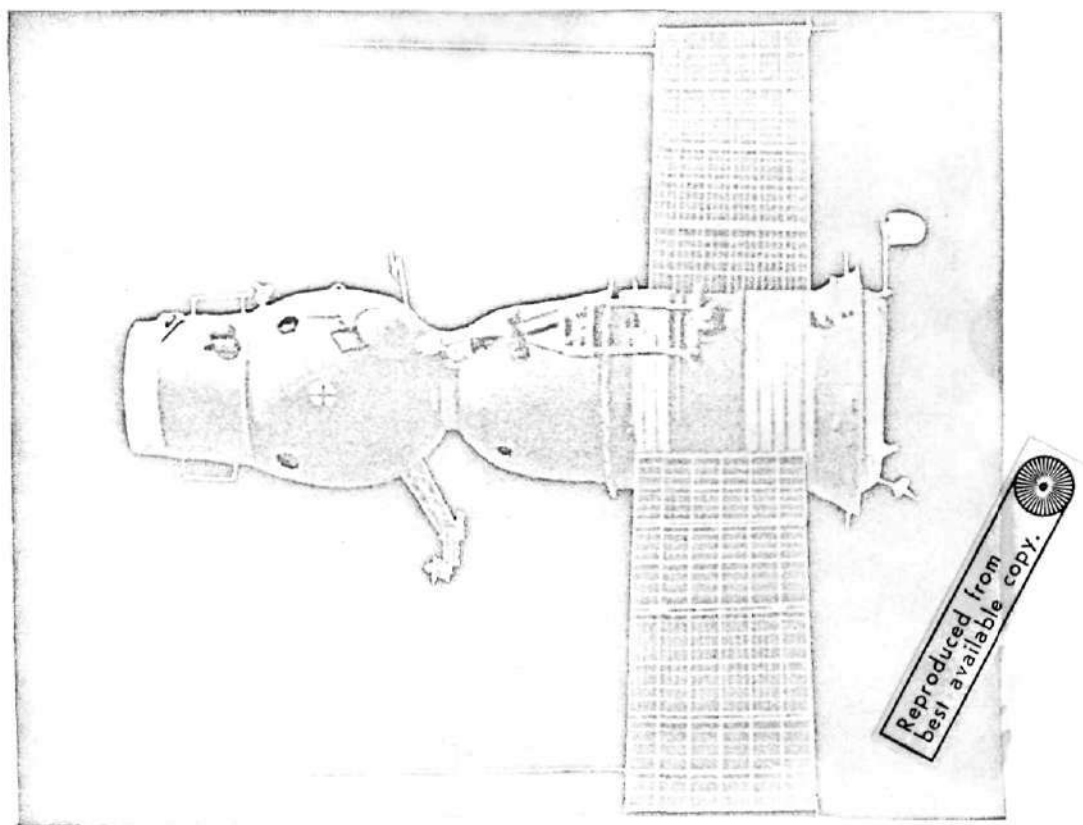


Figure 3. The "Soyuz" spacecraft with a "passive" docking unit.

in the "Soyuz" spacecraft provides for maneuvering to a height of 1,300 km. A low-thrust engine installation is provided to enable the spacecraft to orient itself and to move the spacecraft about during maneuvers. Sensors in the orientation system, the solar batteries (useful area 14 m^2) and the main antennas and feeders are installed on the outside of the accessories bay. A mode that keeps the solar batteries oriented on the sun is included so they have constant illumination. This is done by rotating the spacecraft about an axis directed at the sun at a rate of a few degrees per second.

The on-board television system includes four cameras (two inside the spacecraft, and two outside) and provides transmission of television pictures meeting normal standards (625 lines and 25 frames per second), as well as the possibility of direct transmission to the ground television net.

The stars are used to accurately orient the spacecraft in space. Orbital corrections are made to change the height at which the spacecraft are flying, to enable the spacecraft to fly over specified areas at a definite time, and to dock them. Spacecraft can be docked automatically, or manually.

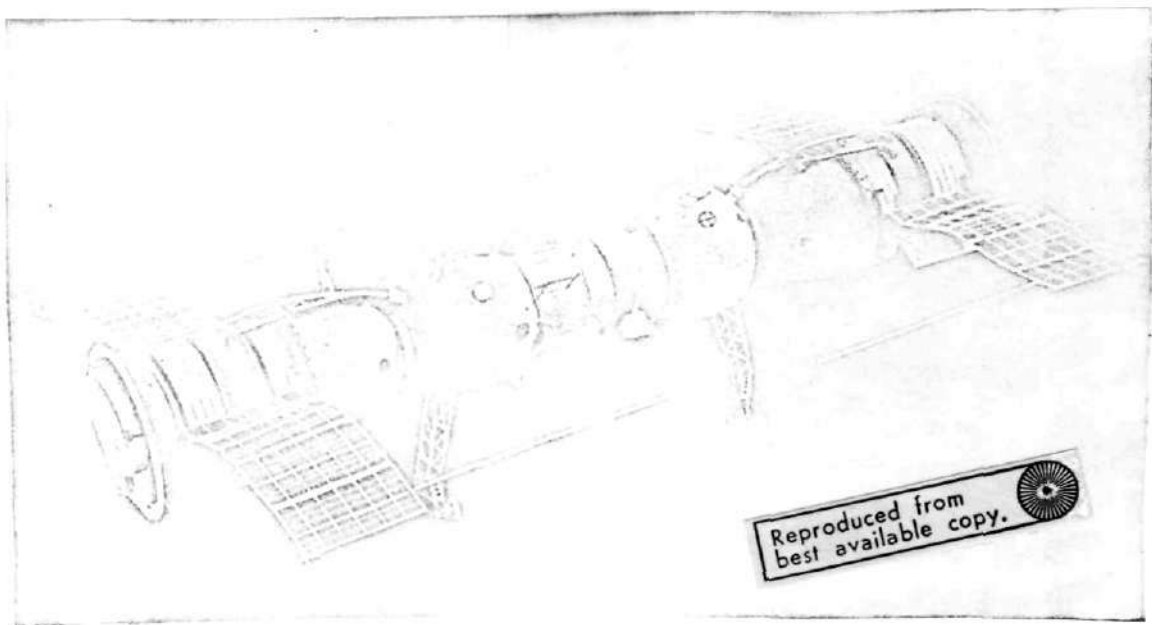
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The docking unit is designed to provide a rigid, mechanical connection of the spacecraft and their electrical circuits. Spacecraft are docked, and the experimental space station is made up of two "Soyuz" spacecraft, as follows. The active satellite (Figure 2) is put into orbit first, followed by the passive satellite (Figure 3). The spacecraft are maneuvered manually and can make long-range approaches from over 1,000 km. The automatic system takes over when the distance has closed to a few kilometers. This system provides the signals whereby the approach correction rockets of the "active" spacecraft fire periodically to provide for the steady closing of the spacecraft at a speed that depends on distance. The spacecraft orient their docking units with respect to each other as the spacecraft are closing.

The spacecraft commanders take over manually at a distance of 100 meters, maintaining necessary orientation, and changing the closing speed. When the spacecraft make contact the relative speed of the spacecraft is reduced to a few tens of centimeters per second in order to avoid a heavy collision, and the docking is made at this speed. The probe of the docking mechanism of the "active" spacecraft enters the socket of the receiving cone of the "passive" spacecraft and mechanical latching occurs. This is followed by the spacecraft being drawn together rigidly, and at this point their electrical plugs are connected.

This is how the world's first experimental space station was assembled and started to function on 16 January 1969. It had four compartments with a total volume of 18 cubic meters (see picture).

Two of the station's compartments could be used as locks allowing egress of the cosmonauts into open space.



On 16 January 1969, Ye. V. Khrunov and A. S. Yeliseyev, members of the crews of "Soyuz-5," donned their space suits and transferred to "Soyuz-4".

"Soyuz" spacecraft return to earth in two stages as follows:

descent from orbit and the flight to reentry;

control of movements after reentry and soft landing.

The commands concerning time to cut in the rockets, and the magnitude of the retrorocket firing, are fed into the programmer-timer on the revolution preceding the spacecraft's descent from orbit. The spacecraft, prior to firing the retrorockets, is oriented in a manner such that the firing will be opposite to the direction in which the spacecraft is moving. This reduces the speed of the spacecraft while the rockets are firing. Orientation can be automatic, or manual.

The engines are cut in a few thousand kilometers from the territory of the Soviet Union and fire for from 140 to 150 seconds. The spacecraft's speed is reduced and it enters another orbit, one intersecting the earth (Figure 4). After a few minutes the recoverable vehicle separates from the orbital and service modules and the controlled descent system is cut in. The principal

advantage of this descent system is that the recoverable vehicle of the "Soyuz" spacecraft lands in an assigned area with great accuracy. The airflow about the vehicle is asymmetrical, so the vehicle has aerodynamic qualities that can be determined as the ratio of the lift to the drag. Maximum effective lift is achieved when the angle of bank is zero, and is zero when the angle of bank is 90°. By controlling the bank with special rockets, it is possible to change the effective value of the lift and make the landing in the specified area. The controlled descent results in a significant reduction in G-forces and the weight of the heat protection is reduced as well. The drogue parachute opens at a height of some 10 km. The main parachute system functions after a short, 7 stabilized descent. The on-board radio beacon is cut in at the same time, and is used by the aircraft and helicopters of the search and rescue group for homing purposes. The soft landing rockets are cut in immediately before landing.

There were eight launches of "Soyuz" spacecraft between 1967 and 1969 (see table). The spacecraft on-board systems were checked and tested during the experiments, manual control systems, and systems for orientation and stabilization in orbit, were developed, spacecraft were maneuvered in orbit with respect to each other, an experimental space station was built, two cosmonauts transferred from one spacecraft to another, and cooperation between a group of spacecraft and ground points located within the USSR and aboard ships on station in different positions on the world ocean, was developed.

"Molniya-1" communication satellites were included in the information transmission system. Flight Engineer V. N. Kubasov of "Soyuz-6" conducted a unique experiment that involved doing different types of welding in space.

The "Soyuz" spacecraft were used for a broad program of scientific research, including a determination of ways to use manned orbital space systems for scientific purposes and for the needs of the national economy.

What will orbital stations look like in the future? Orbital stations can differ in size and weight. Relatively small stations (those weighing from a few tons to tens of tons) will be assembled on the ground. It will be more advantageous to assemble large stations (those weighing hundreds of tons) in orbit.

This will be done by orbiting a succession of individual blocks, and then assembling them to build the station.

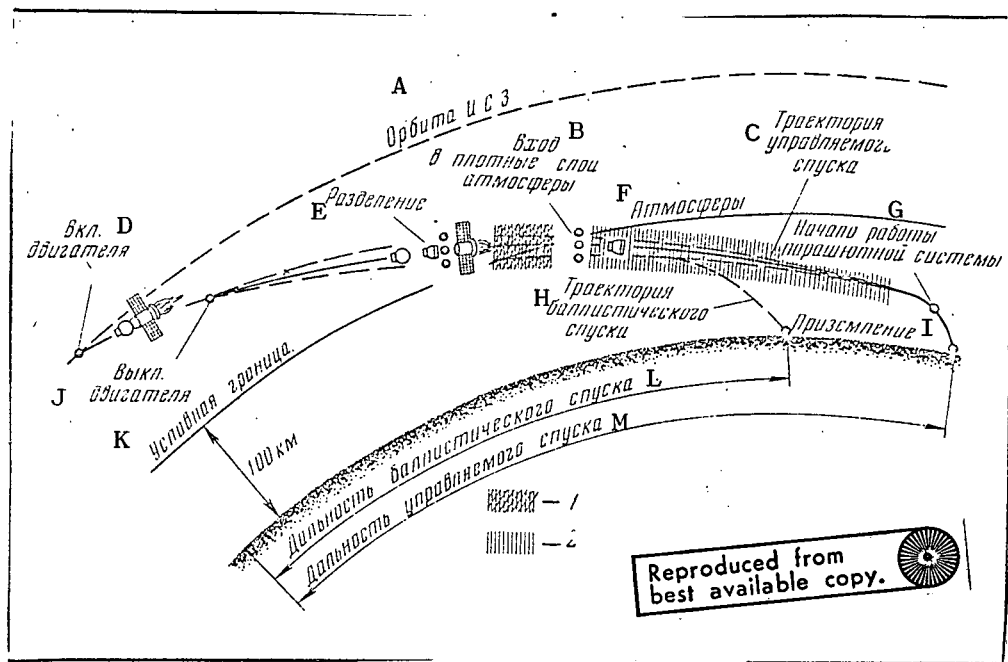


Figure 4. "Soyuz" descent plan.

Legend:

A - orbit of artificial earth satellite; B - reentry; C - controlled descent trajectory; D - rocket fire; E - separation; F - atmospheres; G - parachute system functions; H - ballistic descent trajectory; I - landing; J - rocket shut-down; K - conventional boundary; L - ballistic descent distance; M - controlled descent distance. 1 - section over which programmed turns of the recoverable vehicle are made; 2 - section of control of flight distance.

The station will be made up of different compartments, depending on the the /8 purpose for which the station is intended. But all stations, large and small, obviously will have the basic compartments included in the "Soyuz" class (command, laboratory, orbital, service) and will be fitted with hatches for passage from one compartment to another. One of the projects that is feasible has the space station assembled in orbit from cylindrical compartments to form a "wheel" consisting of a "rim" with 12 to 16 angles, a "hub", and 6 to 8 "spokes."

The station will be rotated slowly to form an artificial gravity. The crew will be able to remain aboard for a long time.

The living and working spaces will be located in the "rim," and the compartments making up the "spokes" will house the service and scientific equipment, storerooms, fuel for the rockets, and other materials.

The "hub" can be the dock for transport spacecraft, and can house the laboratories for conducting scientific experiments under weightlessness conditions. Transport spacecraft will bring up crew replacements, deliver fuel, scientific equipment, and other needed cargo. The "Soyuz" spacecraft already meet many of the requirements imposed on transport spacecraft. It can deliver from the earth crews of manned spacecraft, rescue cosmonauts in emergencies, supply manned stations with certain types of cargoes and with experimental and scientific equipment.

Thus, the Soviet Union has begun to solve successfully the problem of servicing space stations and has built the world's first prototype of an orbital station and a transport spacecraft.

Flights of Soviet Cosmonauts Aboard "Soyuz" Spacecraft

Cosmonauts	Spacecraft	Date of Flight	Weight of spacecraft, kg	Height at perigee, km	Height at apogee, km	Duration of flight
V. M. Komarov	"Soyuz-1"	23-24 January 1967	6450	201.0	224.0	24 h 17 m
Unmanned	"Soyuz-2"	25-28 October 1968	- -	185.0	224.0	
G. T. Beregovoy	"Soyuz-3"	26-30 October 1968	6575	185.1	215.7	95 h 51 m
V. A. Shatalov	"Soyuz-4"	14-17 January 1969	6625	173.0	225.0	71 h 21 m
B. V. Volynov	"Soyuz-5"	15-18 January 1969	6585	200.0	230.0	72 h 46 m
A. S. Yeliseyev						
Ye. V. Khrunov						
G. S. Shonin	"Soyuz-6"	11-16 October 1969	6577	186.1	222.8	117 h 42 m
V. N. Kubasov						
A. V. Filipchenko	"Soyuz-7"	12-17 October 1969	6570	207.4	226.0	118 h 19 m
V. N. Vokov						
V. V. Gorbatko						
V. A. Shatalov	"Soyuz-8"	13-18 October 1969	6646	205.5	222.5	118 h 11 m
A. S. Yeliseyev						
A. G. Nikolayev						
V. I. Sevost'yanov	"Soyuz-9"	11-19 November 1970				424 "59"